

COVERAGE ENHANCEMENT IN WCDMA CELLULAR NETWORK USING REPEATER AND MAHS AMPLIFIER

SAAD ALI ASSI

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University Tun Hussein Onn Malaysia

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DEDICATION

This dissertation is dedicated to my parents, my brothers,
My sisters, my nieces and nephews
My lecturers and all my friends
That have encouraged, guide and inspired me throughout
my journey of education

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First my praise to Almighty Allah for giving me the power and will to complete this study and peace be upon his final Prophet and Messenger Muhammad, SAW.

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I gratefully thank all the staff of the Department of Electrical and Electronic Engineering, UTHM University to give me the chance to study master degree.

May Allah SWA bless all of us!

ABSTRACT

The most popular radio access scheme used for the third generation (3G) system is Wideband Code Division Multiple Access (WCDMA), which provides high data rate services (video conferencing, high bit rate up to 2Mbps) compared with first (1G) and second (2G) generations. To obtain good services, increased number of users and reliable coverage area with minimum implementation cost, the planners must utilize all possible resources to improve capacity and coverage area for the cellular network. The area of study will be a cellular network in urban area with 13*13 km containing 19 sites. Network Planning Strategies for WCDMA (NPSW) is a static simulation program used to plan the radio network for WCDMA system programmed with MATLAB. Studying the impact of the mast head amplifiers and repeaters on the coverage area are investigated. Also, various parameters and their impact on system coverage, like sectorisation (1, 3, 4 and 6 sectors), antenna beamwidth (33°, 65°, 90°, 120°, and an Omni directional antenna). The results obtained show that using mast head amplifiers improve service coverage performance. Repeater system is suitable to solve the problem of the dead zone in WCDMA network with minimum cost.

ABSTRAK

Skema akses radio yang popular digunakan oleh system generasi ketiga (3G) adalah *Wideband Code Division Multiple Access* (WCDMA), yang menyediakan kadar servis data yang tinggi (sidang video, kadar bit yang tinggi sehingga 2Mbps) jika dibandingkan dengan generasi pertama (1G) dan generasi kedua (2G). Bagi mendapatkan servis yang baik, dengan peningkatan jumlah pengguna dan kawasan liputan yang meyakinkan, serta melibatkan kos perlaksanaan yang minimum, perancang mesti menggunakan kesemua sumber yang ada untuk meningkatkan kapasiti dan kawasan liputan untuk rangkaian selular. Liputan kajian yang terlibat adalah rangkaian selular bagi kawasan Bandar dengan keluasan 13*13 km yang terdiri daripada 19 tapak. Strategi Perancangan Rangkaian bagi WCDMA (NPSW) adalah program simulasi statik yang digunakan untuk merancang rangkaian radio bagi system WCDMA yang diprogramkan dengan MATLAB. Kajian tentang impak masthead penguat dan pengulang dalam lingkungan kawasan liputan telah dijalankan. Selain itu, beberapa parameter dan kesannya terhadap kawasan liputan sistem, seperti sektor isasi (1, 3, 4 dan 6 sektor), antenna beamwidth (33°, 65°, 90°, 120°, dan antena Omni berarah). Keputusan menunjukkan penggunaan masthead penguat dapat menambahbaik prestasi liputan servis. Sistem repeater adalah sesuai untuk menyelesaikan masalah zon mati dalam rangkaian WCDMA dengan kos yang minimum.

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LIST OF SYMBOLS AND ABBREVIATIONS

AL_{BS}	BS antenna loss.
$a(hm)$	The UE antenna correction factor.
BS_x position	The BS coordinate in x-axis.
BS_y position	The BS coordinate in y-axis.
CL_{BS}	The cable loss in the base station.
c_{sector}	The correlation coefficients of the two propagation paths from a UE to two sectors at the same site.
c_{site}	The correlation coefficient for two propagation paths from a UE to two sectors at different sites.
D	The intended area sector size.
d_{km}	Distance between UE and BS (km).
ds	Distance between repeater and BS.
Da	Distance between UE and BS (m).
E_b/N_o	The energy per user bit divided by the noise spectral density.
F	The frequency reuse factor.
f	Carrier frequency.
F_B	BS noise figure.
F_R	Repeater noise figure.
G_p	Processing gain.
G_{BS}	BS antenna gain.
G_{UE}	UE antenna gain.
G_D	Repeater donor antenna gain.
G_R	Repeater gain.
G_S	Repeater service antenna gain.
G_B	All gains in the BS.
G_T	The gains and losses between the repeater and BS.
h_b	BS antennas height.
h_m	UE antennas height.
IM_{UL}	Interference margin (noise rise).

$I_{oth,k}$	The other cell interference.
i	The ratio of the other cell interference to the own cell interference.
K	Boltzmann's constant.
LP	Path loss.
\bar{L}_P	Average path loss.
L_p	Link loss between repeater and BS.
L_s	Link loss between UE and repeater.
L_{km}	The path loss from cell k to the UE_m .
N	Number of users in a cell.
N_s	Number of users per sector.
N_{imp}	Number of users with imperfect sectorisation.
NF	Noise figure.
N_m	The background and receiver noise of the UE_m .
N_{iB}	Noise power at the input of the BS.
N_o	Noise power at the output of the BS.
N_{TH}	Thermal noise density.
P_k	Total transmit power of the BS to which link k is established.
P_{km}	The power allocated from BS_k to UE_m .
R	Is the user data rate.
R_j	Data rate of user j .
R_b	Bit rate of the modulated signal.
S_{iB}	Signal power at the input of the BS.
S_o	Signal power at the output of the BS.
T	The noise temperature.
T_{aB}	Antenna noise temperature at the BS antenna.
T_{aR}	Antenna noise temperature at the repeater service antenna.
T_{eB}	Inherent noise temperature of the BS.
T_{eR}	Inherent noise temperature of the repeater.
v_j	Activity factor of user j .
W	Chip rate.
W_r	Signal bandwidth.

η_{UL}	Uplink load factor.
η_{DL}	Downlink load factor.
A	The orthogonality factor.
α_j	The orthogonality factor of user j.
α_i	Is the direction of the UE relative to the BS.
ζ	Log-normal random variable represents the shadowing attenuation.
ξ	Fading propagation path for UE.
σ	Standard deviation of shadowing.
φ	The azimuth angle.
ϑ	The elevation angle.
β	The vertical angle between BS and UE antenna.
Δ	The number of sectors per cell.
ϵ	Overlap angle between sectors.
1G	First Generation.
2G	Second Generation.
3G	Third Generation.
3GPP	Third Generation Partnership Project.
4G	Fourth Generation.
AMPS	Advanced Mobile Phone Service.
AMR	Adaptive Multi Rate.
AGC	Automatic Gain Control.
BoD	Bandwidth on Demand.
BS	Base Station.
BPSK	Binary Phase Shift Keying.
C/I	Carrier to Interference Ratio.
CDF	Cumulative Distribution Function.
CN	Core Network.
C_u	Is the electrical interface between the USIM smartcard and the ME.
CPICH	Common Pilot Channel.
COST 231	The European CO-operation in the field of Scientific Technical research.

DL	Downlink.
DS	Direct Sequence.
DCH	Dedicated Channel.
DS-SS	Direct Sequence Spread Spectrum.
DTX	Discontinuous Transmission.
DS-CDMA	Direct Sequence Code Division Multiple Access.
EDT	Electrical Down Tilt.
ETACS	European Total Access Cellular System.
EIRP	Effective Isotropic Radiated Power.
EF_B	Effective Base Station noise figure.
EF_R	Effective noise figure for Repeater.
FDD	Frequency Division Duplex.
FH-SS	Frequency Hopping Spread Spectrum.
GSM	Global System for Mobile.
GPS	Global Positioning System.
HCS	Hierarchical Cell Structure.
HSPA	High Speed Packet Access.
IS-95	Interim Standard-95.
I_u	The interface used for communication between the RNC and the core network.
I_{ub}	The interface used for communication between the NodeB and the RNC.
I_{ur}	The interface used for communication between different RNCs.
IF-HO	Inter Frequency Handover.
IP	Internet Protocol.
ISI	Inter-Symbol Interference.
LOS	Line of Sight.
LFS	Free Space Loss.
ME	Mobile Equipment.
MRC	Maximal Ratio Combining.
MHAs	Mast Head Amplifiers.
MDT	Mechanical Down Tilt.
NPSW	Network Planning Strategies for Wideband CDMA.

NF	Noise Figure.
RAN	Radio Access Network.
RRHs	Remote Radio Heads.
RNC	Radio Network Controller.
RRM	Radio Resource Management.
RNP	Radio Network Planning.
RF	Radio Frequency.
SHO	Soft Handover.
TDD	Time Division Duplex.
TH-SS	Time Hopping Spread Spectrum.
UE	User Equipment.
UL	Uplink.
UMTS	Universal Mobile Telecommunication System.
USIM	UMTS Subscriber Identity Module.
UTRA	Universal Terrestrial Radio Access.
UTRAN	UMTS Terrestrial Radio Access Network.
U_u	The interface used for communication between the Node and the UE.
WCDMA	Wideband Code Division Multiple Access.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The cellular communication evolution has been very rapid in the past decade, the current mobile communication system family can be categorized into different generations; Analog based first generation (1G), circuit switched second generation (2G), packet switched third generation (3G) and lately Internet Protocol (IP) based fourth generation (4G). However, with the technology developments, each proceeding generation provides better quality, capacity and bandwidth efficient thus allowing wide range of services to be offered [1][2].

The most popular radio access scheme used for 3G system is Wideband Code Division Multiple Access (WCDMA), which allows greater capacity and higher data rate (up to 2Mbps) [3]. However, WCDMA radio access technique results in new difficulties for the radio network planners, because it allowed to use common frequencies in all cells of the network. Therefore, the coverage planning for WCDMA network is done because of the other to own cell interference phenomenon [4].

For good services, the aim is to increase reliable coverage, therefore for an operator, it is most important to utilize all possible resources to improve the network coverage area (cost-effective coverage improvement strategies are needed to maintain the network profitable).

1.2 Problem Statement

The most popular radio access scheme used for the third generation (3G) system is Wideband Code Division Multiple Access (WCDMA), which provides high data rate services (video conferencing, high bit rate up to 2Mbps) compared with first (1G) and second (2G) generations. To obtain good services, increased reliable coverage area with minimum implementation cost, the planners must utilize all possible resources to improve coverage area for the cellular network.

1.3 Objectives

The objectives of this project are:

- I. To investigate the influence of the mast head amplifiers and repeaters on the coverage area.
- II. To improve the network coverage area (cost-effective coverage improvement strategies are needed to maintain the network profitable).

1.4 Scope of Project

- I. The area of study is a cellular network in urban area with 13*13 km containing 19 sites.
- II. Network Planning Strategies for WCDMA (NPSW) is a static simulation program used to plan the radio network for WCDMA system programmed with MATLAB.

1.5 Project Outline

The project consists of five chapters. Chapter one includes an introduction and the objectives, motivation of work, scope and thesis outline.

Chapter Two gives a brief explanation of the previous related literatures and detailed explanation for WCDMA system and radio network planning.

Chapter Three describes planning tool with types, explain Network Planning Strategies for Wideband CDMA (NPSW) program and explain methods of coverage area enhancement used in the present project.

Chapter Four gives a complete descriptions of the proposed simulation model and results as well as the discussions of results.

Chapter Five includes the conclusions obtained from this project as well as some of future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Wireless communication has encountered enormous development during the last three decades. The developments started from the 1G analog systems in 1983 such as Advanced Mobile Phone Service (AMPS) and the European Total Access Cellular System (ETACS) [1].

In the early 1990s, the 2G digital cellular systems began to be deployed, such as Global System for Mobile (GSM), while 1G can support voice service only and no privacy. 2G provides voice service as well as low data bit rate service, so the demand for multimedia and high data rate services (up to 2 Mbps) has led to the development of the 3G system [3][4].

The first 3G system operated in October, 2001 in Japan, using the WCDMA technology. The most popular 3G systems are the Universal Mobile Telecommunication System (UMTS) and CDMA2000 which are regarded as an evolution of 2G Interim Standard 95 (IS-95) and GSM respectively. The 3G systems are designed to provide multimedia and high data rate service in addition of voice services [3].

Table 2.1 illustrates the evaluation of mobile communication systems.

Table 2.1: Evaluation of Mobile Communication Systems [1]

First Generation	Second Generation	Third Generation
AMPS, ETACS	GSM, IS-95	UMTS, CDMA2000
Speech service	Speech service Low data rate service	Speech service Multimedia service High data rate service
Analog transmission	Digital transmission	Digital transmission

2.2 WCDMA System

2.2.1 WCDMA in 3G Systems

The 3G systems are designed for multimedia communication, personal-to-personal communication can be enhanced with high quality images, video, and high data rate. WCDMA technology has emerged as the most widely is the 3G systems and with specification created in 3G Partnership Project (3GPP). With 3GPP, WCDMA is called Universal Terrestrial Radio Access (UTRA) either Frequency Division Duplex (FDD) or Time Division Duplex (TDD). WCDMA is a multiple access technology used in UMTS. The user information bits are spread over a band of 5MHz, which is nominal of all 3G WCDMA. This bandwidth is chosen because it is sufficient to provide data rate of 144 and 384 kbps and even 2 Mbps in good conditions [3][5].

2.2.2 Summary of the Main Parameters in WCDMA

Table 2.2 summarizes the main parameters of the WCDMA air interface.

Table 2.2: The Main Parameters of WCDMA System [5]

Multiple access technique	DS-CDMA
Duplexing mode	FDD and TDD
Chip rate	3.84 Mcps
Frame length	10 ms
Service multiplexing	Multiple service in connection
Detection	Coherent detection
Handover	Soft handover
Multi user detection ,smart antenna	Supported by the standard , optional in the implementation

The effective parameters of WCDMA are presented in this section [5][6]:

- WCDMA is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system. User information bits are spread over a wide bandwidth (5 MHz) by multiplying the data with a spreading code, in order to support very high bit rates (up to 2Mbps), the use of a variable spreading factor and multicode connections are supported. An example of this arrangement is shown in Figure 2.1.
- The chip rate of 3.84Mcps leads to a carrier bandwidth of approximately 5 MHz. The inherently wide carrier bandwidth of WCDMA supports high user data rates and also has certain performance benefits, such as increased multipath diversity.
- WCDMA supports highly variable user data rates, in other words the concept of obtaining Bandwidth on Demand (BoD) is well supported. The user's data rate is kept constant during each 10 ms frame. However, the data capacity among the users can be changed from one frame to another Figure 2.1. also shows an example of this feature.

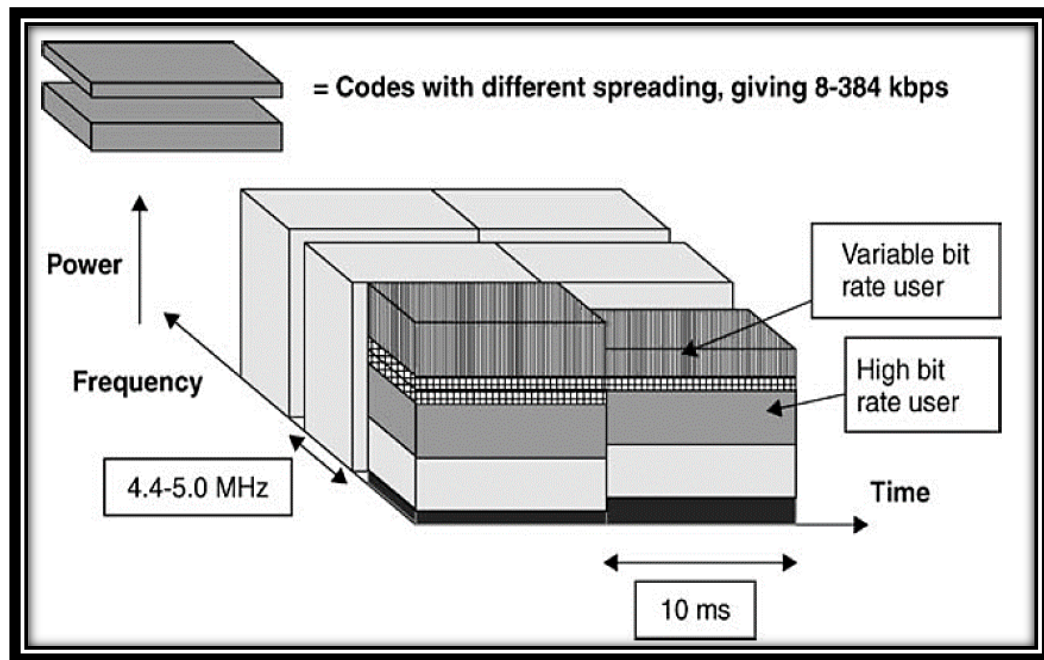


Figure 2.1: Allocation of bandwidth in WCDMA in the time– frequency– code space [5]

- WCDMA supports two basic modes of operation: FDD and TDD. In the FDD mode, separate 5MHz frequencies are used for the uplink and downlink respectively, whereas in TDD only one channel of 5MHz is time-shared between both the uplink and downlink. Uplink is the connection from the mobile to the base station, and downlink is that from the base station to the mobile.
- WCDMA supports the operation of asynchronous base stations, so that, unlike the case in the synchronous IS-95 system, there is no need for a global time reference such as a Global Positioning System (GPS).
- WCDMA employs coherent detection on uplink and downlink based on the use of pilot symbols or common pilot. In IS-95 coherent detection is only used on the downlink. The use of coherent detection on the uplink will result in an overall increase of the coverage and the capacity on the uplink.
- WCDMA is designed to be deployed in conjunction with GSM. Therefore, handover between GSM and WCDMA are supported.

2.2.3 Classification of Services Provided in WCDMA System

WCDMA system offers different types of service, and each service have certain data rate. The following are common data rate in WCDMA system [5]:

- 8kbps: This service provides the basic speech service.
- 12.2kbps: This service provides good quality speech service, including Adaptive Multi Rate (AMR) codec (AMR is a speechencoder).
- 64kbps: This service provides good quality speech and data service, with simultaneous data and AMR speech capability.
- 144kbps: This service provides video telephony (real time) or various other data services.
- 384kbps: This service is being further enhanced from 144 kbps, to deal with advanced packet data methods provided in WCDMA (non real time).
- 2Mbps: This service has been defined for the downlink direction only.

2.3 Spreading and De-spreading

2.3.1 WCDMA and the Spreading Concept

Generally CDMA systems are based on spread spectrum communication. In CDMA systems, the communication of multiple users over the same radio channel bandwidth is separated through different spreading codes, which are assigned uniquely to each user at the time of connection set up. The spreading codes are mutually orthogonal to each other (they have zero cross-correlation) [7].

There are three types of spread spectrum techniques [8]:

- Direct Sequence Spread Spectrum (DS-SS).
- Frequency Hopping Spread Spectrum (FH-SS).
- Time Hopping Spread Spectrum (TH-SS).

The most common technique used in cellular system is the DS-SS which is used for instance in WCDMA system.

2.3.2 Spreading and De-spreading in DS-SS

In DS-SS each bit in the original signal is represented by multiple bits in the transmitted signal using spreading pseudo random code. Figure 2.2. shows the spreading and the de-spreading operation. The user's data is assumed to be Binary Phase Shift Keying (BPSK) modulated signal having bit rate R_b . Spreading is the X-NOR of each user bit with M chips ($M=8$) spreading code. Then, the transmitted signal should be 8 times more than the user data. At the receiver side, the received signal is X-NOR by the same spreading code used at the transmitter to detect the user's original data [5].

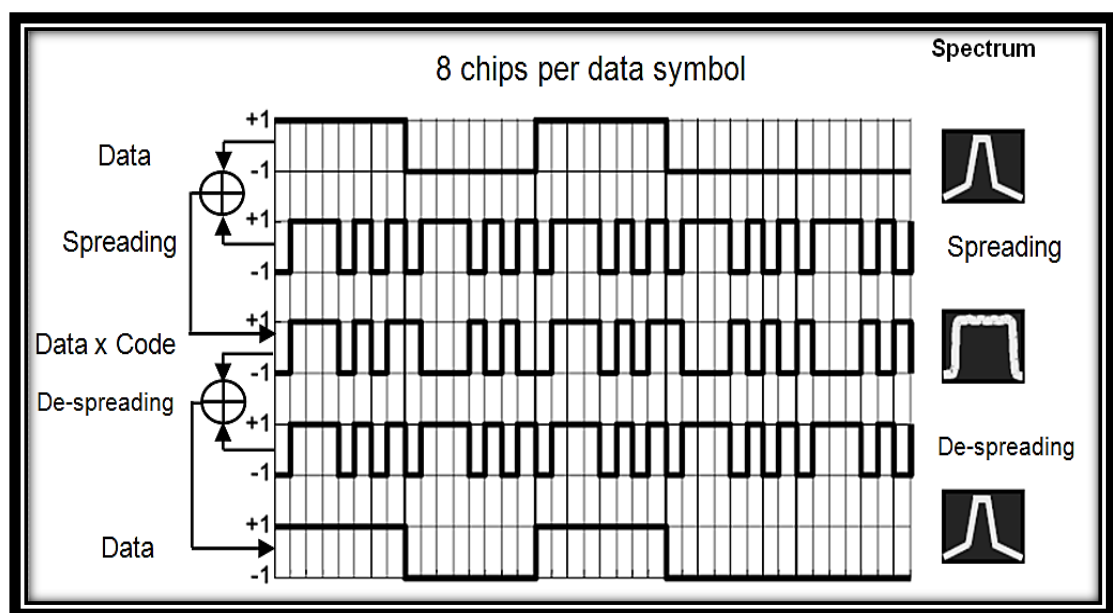


Figure 2.2: Spreading and the De-spreading Operation [4]

2.3.3 Processing Gain (Spreading Factor)

The ratio between the transmitted modulation bandwidth and the information signal bandwidth is called the Processing Gain (G_p), as shown in equation (2.1) [9]:

$$G_p = \frac{W}{R} \quad 2.1$$

where W is the chip rate and R is the user data rate.

In WCDMA, the chip rate (w) is kept constant (3.84Mcbps) and thus the processing gain only depends on the user's data rate. The higher user's data rate gives lower processing gain. Thus, it is harder for the receiver to detect the signal correctly, due to the gain which added to the signal received at mobile is very low [10].

Table 2.3 illustrates WCDMA data rate with processing gain.

Table 2.3: WCDMA Data Rate with Processing Gain [9]

User Data Rate (R) (kbps)	Processing Gain (dB)
12.2	25
64	18
144	15
384	10

2.3.4 Scrambling

In addition to spreading, a part of the process in the transmitter is the scrambling operation. The scrambling codes are needed to identify User Equipment (UE) or Base Station (BS). Scrambling is used after spreading, so it does not change the signal bandwidth but only makes the signals from different sources separable from

each other. Scrambling is done after spreading at the transmitter side and before de-spreading at the receiver as shown in Figure 2.3. [11].

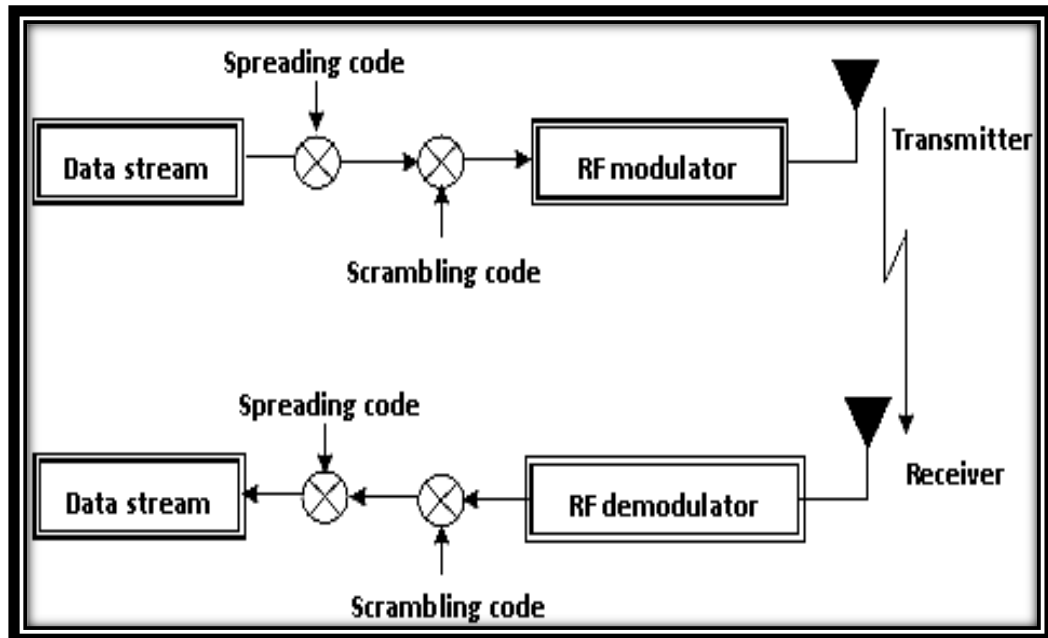


Figure 2.3: Spreading and Scrambling Process

2.3.5 WCDMA System Codes

The task of each of channelization codes and scrambling codes varies in the uplink and the downlink [2].

Table 2.4 illustrates WCDMA system codes and their applications.

Table 2.4: WCDMA system codes [2][5]

Code type	Uplink	Downlink
Scrambling Codes	Users separation	Cell separation
Channelization Codes	Separation data and control channels from the same UE	Separation of downlink connection to different users within one cell

2.4 Multipath and RAKE Receiver

2.4.1 Multipath

Multipath is a phenomenon that happens in the channel of mobile systems when the transmitted signal arrives at the receiver via different paths due to reflection, diffraction and scattering resulting in fading. There is only one transmitted signal, due to obstacles like buildings, hills, trees, and so on, in the signal path that cause different signals to arrive at the receiver from various directions with different delays [7]. Figure 2.4. illustrates three propagation components.

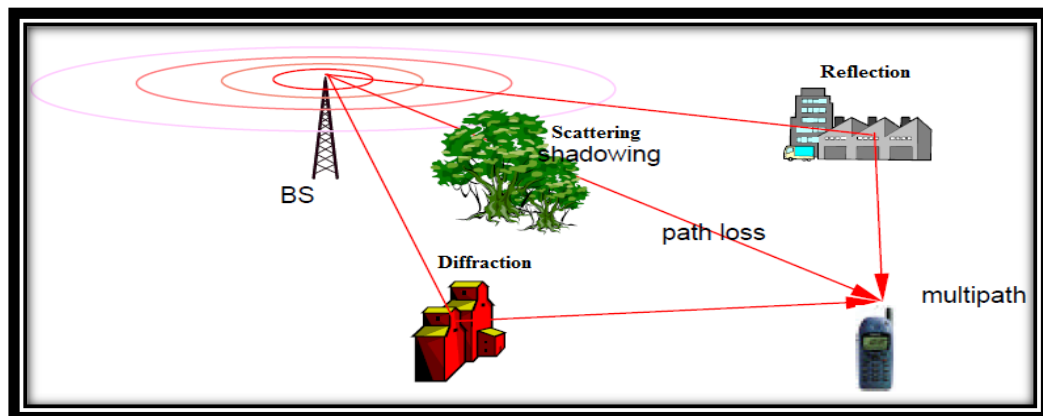


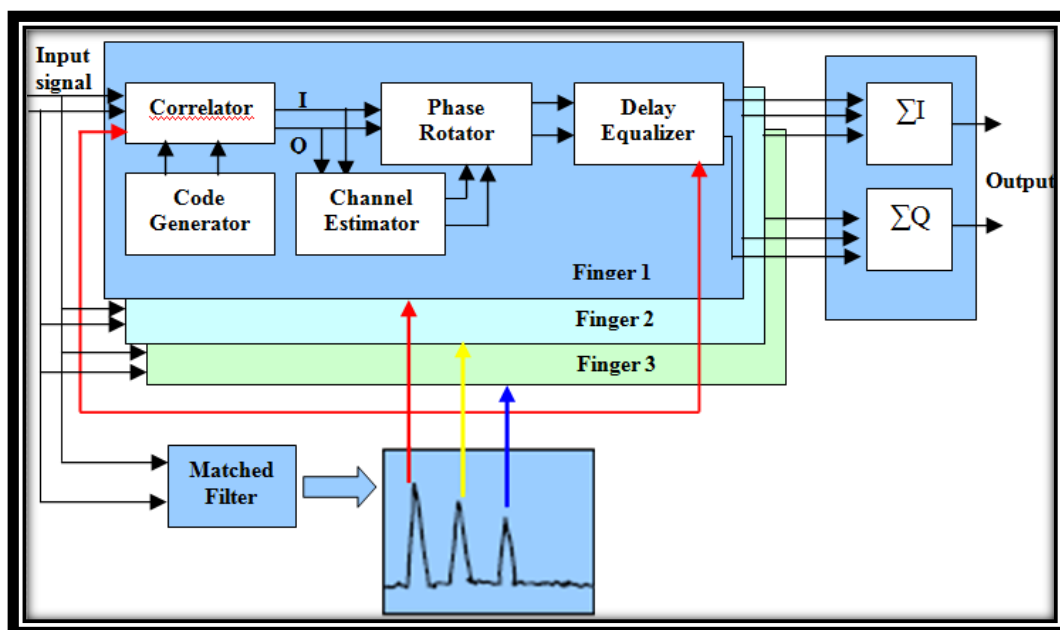
Figure 2.4: Propagation Component

where [12]:

- **Path loss:** decay of the signal strength with distance.
- **Slow fading (Shadowing):** is due to obstruction of the signal by natural obstacles.
- **Fast fading:** due to the multipath reflection of the transmitted signal.

2.4.2 RAKE Receiver

In a multipath channel, the original transmitted signal is reflected by obstacles before reaching the receiver and the receiver receives several copies of the original signal with different delays. These multipath signals can be received and combined using a RAKE receiver. The RAKE receiver consists of several sub-receivers known as correlators or fingers. RAKE receiver is a radio receiver designed to reduce the effect of multipath fading. Each correlator individually detects and processes one multipath component [3]. Then, the outputs of the correlators are combined together using Maximal Ratio Combining (MRC) algorithm to gain reliable signal that leads to improve the system performance. Both BS and UE use RAKE receiver with the difference number of fingers (3 fingers in UE, while 4 or 5 fingers in BS) [13]. Figure 2.5. shows a RAKE receiver with three fingers, each finger is equipped with a correlator, channel estimator and phase rotator. The channel estimator tunes the amplitude according to certain attenuation factor and phase rotator equalizes the phases of fingers, before the signal from each finger is combined using certain



algorithm such as MRC [2].

Figure 2.5: RAKE Receiver

2.5 Frequency Reuse

Frequency reuse is a parameter of how the same channels can be reused in neighboring cells. In WCDMA all users in the same cell share the same frequency spectrum simultaneously, while in 2G systems like GSM use a typical reuse pattern as 7 cells [4], as shown in Figure 2.6a. Cells of the same letters use the same channel frequencies. In WCDMA as illustrated in Figure 2.6b, it has the frequency reuse factor equal to one, this means that all the cells share the same duplex frequencies.

Practically the frequency reuse factor (F) can be calculated in WCDMA system according to equation (2.2) [13]:

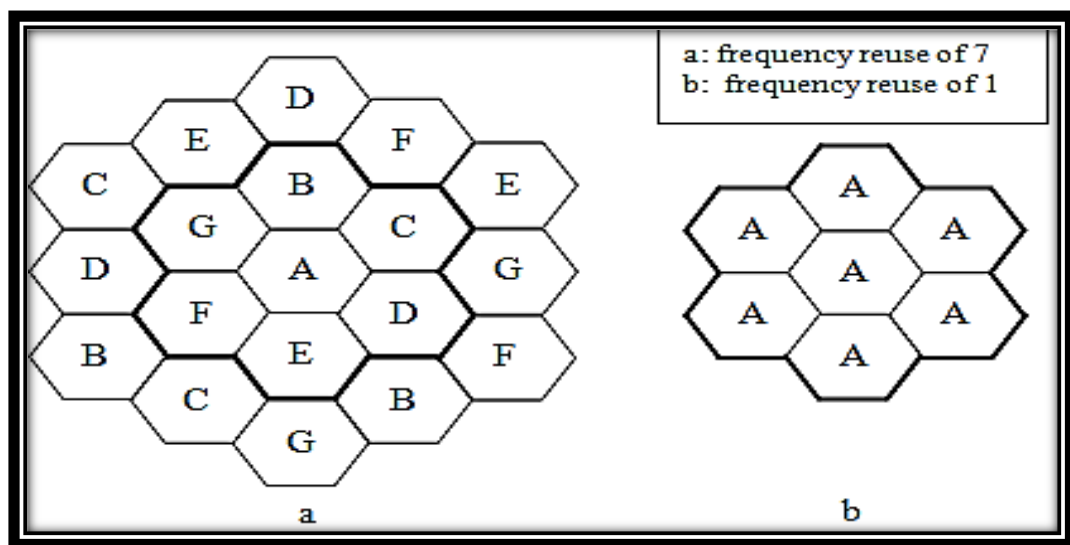


Figure 2.6: Frequency Reuse Factor [1]

a: Frequency reuse of 7.

b: Frequency reuse of 1.

$$F = \frac{1}{1+i} \quad 2.2$$

where i is the ratio of the other cell interference to the own cell interference.

2.6 Power Control and Handover in WCDMA

2.6.1 Power Control in WCDMA

In WCDMA system all users use the same duplex frequency at the same time. Hence the users will interfere with each other and could degrade the performance of the system. Therefore, it is important to control the transmit power. The power control feature ensures that both the user and control transmitted power levels are such that they cause minimum interference to other users in the system. The power control algorithm adjusts the transmit power levels depending on the signal level and offered services [2].

There are three types of power control in WCDMA [6]:

1) Open-loop power control.

Open loop power control is performed in UE, UE examines the received power level measurements of Pilot signal to set its initial power level.

2) Closed-loop power control.

In closed loop power control, the transmitter of UE adjusts the transmitted power in accordance with the transmit power control commands transmitted by BS to achieve a better Signal to Interference Ratio (SIR) nearest to given target SIR.

3) Outer-loop power control.

The outer loop power control is needed to keep the quality of communication at the required level by setting the target for the fast power control.

2.6.2 Handover in WCDMA

One of the most important features of wireless cellular communication is the provision of mobility for the users. Therefore, each mobile user went entire a cell or network without the loss of connections its cell or network, this process is called handover. Handover is divided into two categories: hard and soft handover [5]. Both hard and soft handover schemes are supported in WCDMA. Hard handover (inter frequency handover) is used when the carrier frequency changes between the cells (for WCDMA 900MHz to WCDMA 2100MHz). In normal WCDMA operation, soft handover (SHO) is the most common handover scheme. In soft handover the mobile is connected simultaneously to two or more BS as shown in Figure 2.7. [5][6].

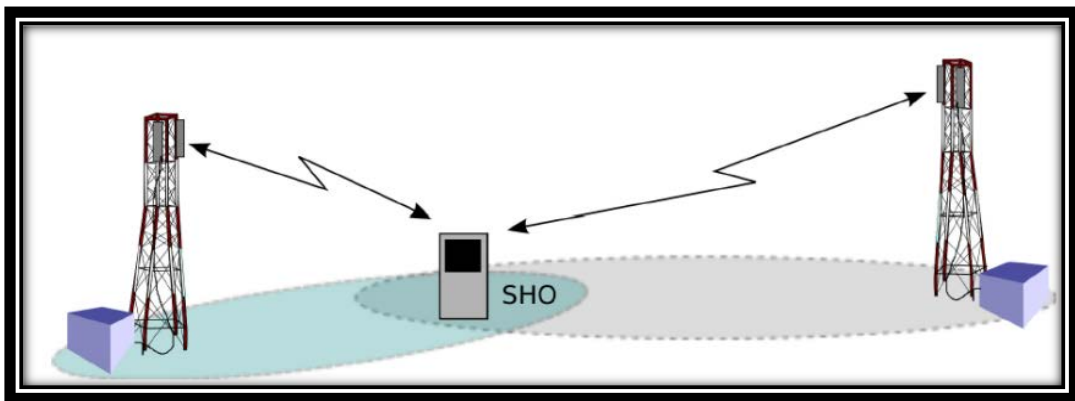


Figure 2.7: Soft handover between two cells

Besides SHO, it is also possible to maintain simultaneous connections to different sectors within the same serving BS sector cell. This scheme is called softer handover as shown in Figure 2.8. [6].

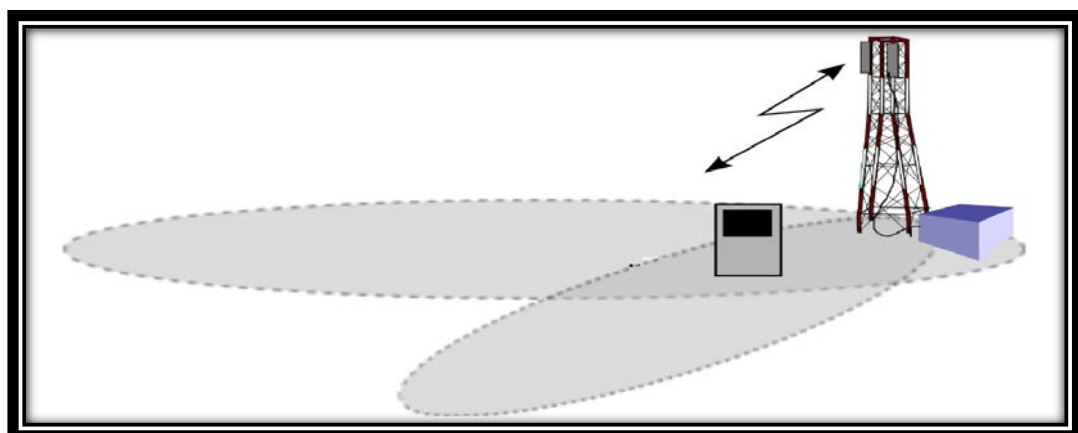


Figure 2.8: Softer handover between two sectors

2.7 Radio Access Network Architecture for WCDMA

In 3GPP, the architecture of WCDMA system such as UMTS is divided into three major parts as illustrated in Figure 2.9. [5]:

- 1) User Equipment (UE).
- 2) UMTS Terrestrial Radio Access Network (UTRAN).
- 3) Core Network (CN).

In UMTS the connection between mobile terminal and the core network is established by WCDMA Radio Access Network (RAN).

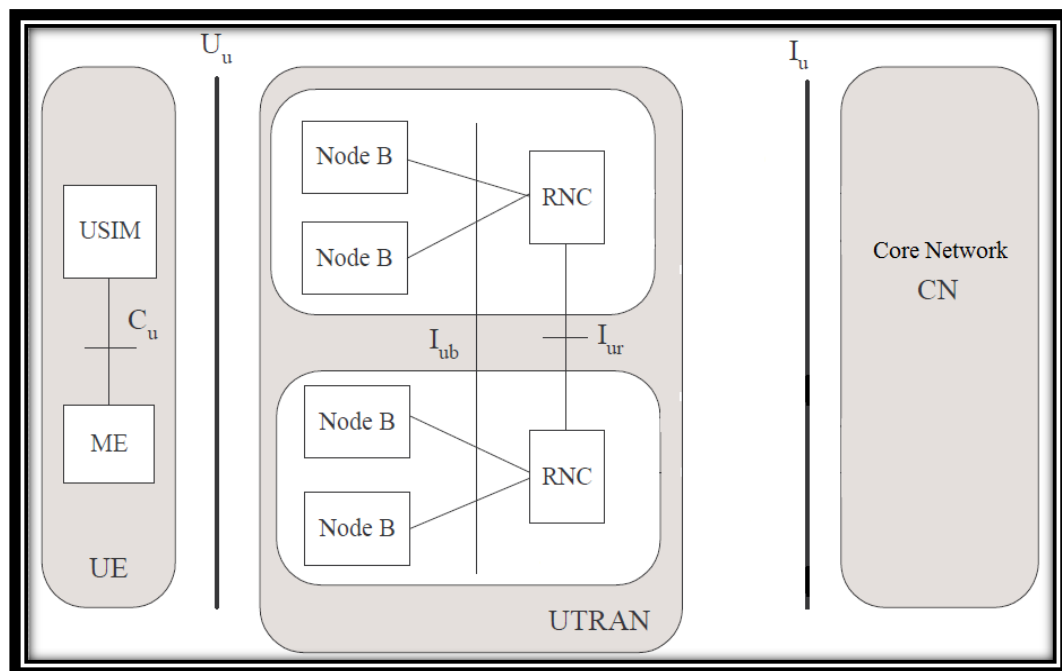


Figure 2.9: WCDMA Radio Access Network

- The UE consists of two parts :
 - 1) The Mobile Equipment (ME) is the radio terminal used for radio communication.
 - 2) The UMTS Subscriber Identity Module (USIM) is a smart card that holds the subscriber identity, performs authentication algorithms, and stores authentication and encryption keys and some subscription information that is needed at the terminal.

- UTRAN consists of two parts:
 - 1) The Node B converts the data between the I_{ub} and U_u interfaces.
 - 2) The Radio Network Controller (RNC), which may control one or more node Bs.

Note: the term 'Node B' from the corresponding 3GPP Specifications, the more generic term 'Base Station' means exactly the same thing [5].

The following main interfaces are shown in the Figure2.9. [5]:

- C_u interface: This is the electrical interface between the USIM smartcard and the ME.
- U_u interface: This is the WCDMA radio interface, is the air interface between UE and UTRAN.
- I_u interface: This connects the UTRAN and the CN.
- I_{ub} interface: This is the air interface that connects a node B with the radio network controller (RNC).
- I_{ur} interface: This interface allows soft handover between RNCs from different manufacturers and therefore, complements the open I_u interface.

2.8 Radio Network Planning

The target of the radio network planning in general is to provide maximum network coverage and system capacity together with sufficient quality for the planning area using reasonable implementation cost. There are three major radio system planning phases in WCDMA and are identified as [3][4]:

- Dimensioning.
- Detailed Radio System Planning.
- Optimisation.

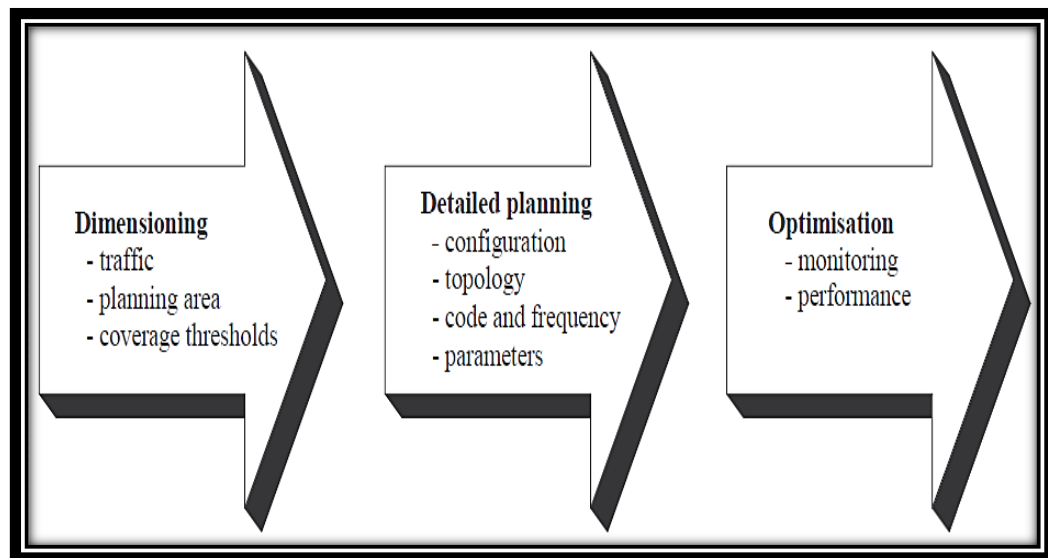


Figure 2.10: Radio network planning process in WCDMA

2.8.1 Dimensioning

In the dimensioning phase, the main target is to obtain an estimation of the required radio network configuration and deployment strategy. The planner estimates the initial traffic requirements, the planning area, the initial coverage thresholds are needed, and the average antenna height must be defined in this phase in order to clarify the radio propagation channel characteristics in the next stage [2].

2.8.2 Detailed Planning

The objective of detailed radio system planning is to define the final network configuration in terms of the base station site configuration and location together with antenna configurations. Detailed radio system planning consists of configuration planning, topology planning, coding (spreading and scrambling codes), frequency planning and parameters planning[14].

- Configuration planning :

Link budget (power budget) is the main tool in configuration planning phase. In the link budget calculations, for example gain of the antenna elements and the amplifiers, losses, and coverage thresholds are decided. The results of the link budget calculations is the uplink and the downlink maximum allowable propagation losses [15].

Table 2.5 illustrates an example of radio link budget for speech and data services.

- Topology planning :

The results of link budget calculations in configuration planning are used in the topology planning in the coverage area estimation using the related propagation models. Since WCDMA offers multiple services (voice, video call, packet switched) then each service has coverage probability [6]. Topology planning phase is described more comprehensively in section (2.9).

Table 2.5: Example of a radio link budget for speech and data services [4][15].

	Speech		Data			
Parameters	Uplink	Downlink	Uplink	Downlink	symbol	Units
Data rate	12.2	12.2	64	384	R	kbps
Load	50	50	30	75		%
Thermal noise density	-174	-174	-174	-174	G	dBm/Hz
Receiver noise figure	4	8	4	8	F	dB
Noise power at receiver	-104	-100	-104	-100	$H=G+F+10\log(3.84*10^6)$	dBm
Interference margin	3	3	2	6	I	dB
Total noise power at receiver	-101	-97	-102	-94	$J=I+H$	dBm
Processing gain	25	25	18	10	$PG=10\log(3.84*10^6/R)$	dB
Eb/No required [14]	5.1	7.4	1.7	3.4	L	dB
Receiver sensitivity	-120.9	-114.5	-118.3	-100.6	$M=L-PG+J$	dBm
RX						
Rx antenna gain	18	0	18	0	N	dBi
Body/cable loss	5	2	5	2	O	dB
Soft handover diversity gain	2	3	2	3	S	dB
Power control headroom	3	0	3	0	T	dB
Required signal level	-132.9	-115.5	-130.3	-101.6	$Req=M-N+O-S+T$	dBm
TX						
TX power per connection	21	30	24	30	PPC	dBm
Body/cable loss	2	5	2	5	OO	dB
TX antenna gain	0	18	0	18	NN	dBi
Peak EIRP ⁽¹⁾	19	43	22	43	$EIRP=PPC-OO+NN$	dBm
Max propagation loss	151.9	158.5	152.3	144.6	$Max L=EIRP-Req$	dB

⁽¹⁾ Effective Isotropic Radiated Power (EIRP).

- Code, frequency and parameters planning :

The code planning phase in WCDMA is quite straightforward. Typically, in the frequency planning phase, the carrier usage for macro and micro cells is defined separately. Parameters planning include signalling parameter and Radio Resource Management (RRM) strategies, which contain power control,

handover, and congestion control [14].

2.8.3 Optimisation

The optimisation phase is an adjustment process based on realistic changes that were not taken into account in the original radio system planning. Optimisation includes, for example verification of call, establishments and functionality of handover. Moreover, monitoring is also included in optimisation phase, since network performance is monitored, and parameters, like antenna tilt can be adjusted towards their optimum values [4][16].

2.9 Topology Planning

In WCDMA network coverage, the same carrier frequency is used over the radio network, and moreover other users signals are seen as additional interference. Hence, attention should be paid on coverage planning phases simultaneously in WCDMA radio network planning [16]. The name of coverage planning is topology planning. Topology planning defines the base station site configuration and location together with antenna configuration. The topology planning phase can be divided into:

- **Initial Topology Planning.**
- **Detailed Topology Planning.**

2.9.1 Initial Topology Planning (Coverage)

In WCDMA network transmit power is shared between mobiles in downlink (one-to-multiple) and signal reception sensitivity depends on the interference level of a cell. Thus, in WCDMA networks, the coverage thresholds in a cell depend on the number of users and their bit rates. Therefore, the coverage thresholds have to be determined for each cell separately depending on the offered services. Figure 2.12. illustrates different cell coverage with different data rates [15][14].

WCDMA network coverage can be roughly divided into two parts: common pilot channel (CPICH) and dedicated channel (DCH) coverage. CPICH is used for channel estimation, handover measurements and cell selection/reselection procedures (define cell border). Typically 5 - 10% of the total base station power is reserved for CPICH. DCH is used for transfer data rate to the user [4][17].

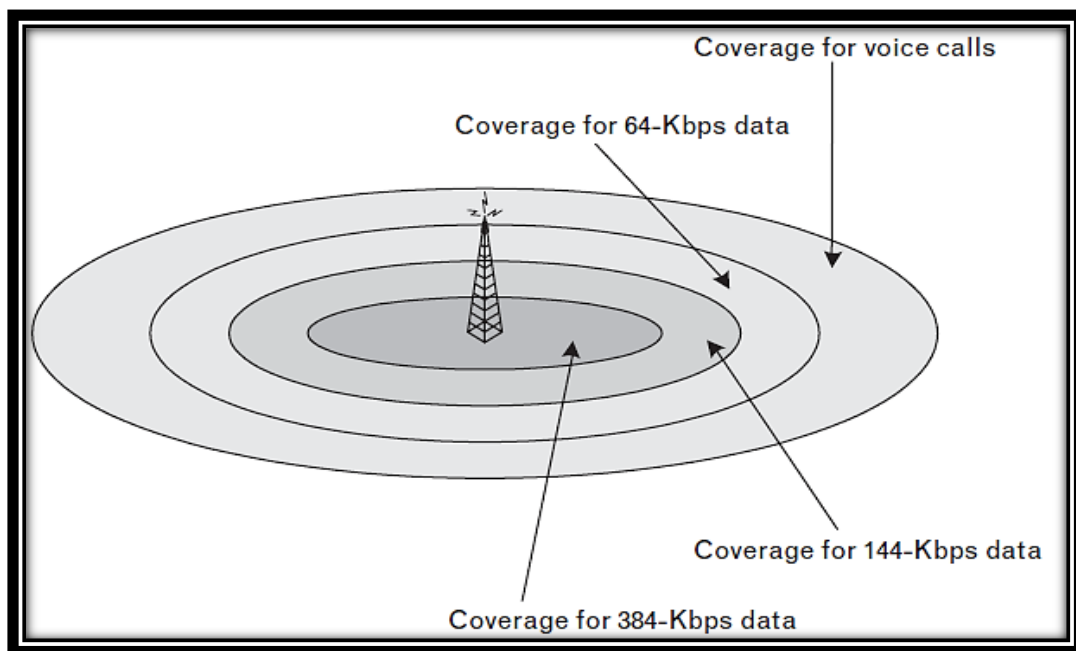


Figure 2.11: Data rate with coverage [3]

2.9.2 Detailed Topology Planning

In the detailed topology planning phase, the network parameters and configurations of the initial topology planning phase are moved into the Radio Network Planning (RNP) tool or simulator. RNP tool for WCDMA radio network planning must to have at least the following properties [14]:

- User interface for controlling the data.
- Possibility to utilize digital maps.
- Site and antenna configuration editors.
- Propagation model editor.
- Coverage predictions.
- Traffic modeling.
- Capacity and performance simulator.

Digital map is one of the essential elements required in a RNP tool. The possibility to change the site locations and configurations together with antenna configuration is important for changing the network topology, since traffic distribution is also a very important parameter, and has a strong effect on topology planning [15]. The importance of traffic model has to be emphasized. The more accurate traffic models, the more precisely the load of the network. Coverage predictions simulations are performed by utilizing a RNP tool. The simulation results include a coverage analysis of certain planning area when actual base station site configurations are used. New simulations are required when any topology technical network element is modified, because interference level between neighbor cells has to be recalculated. In order to achieve the maximum coverage, the base stations sites configurations (number of sectors, sectors orientation, site distance) have to be optimized for different site locations and antenna configurations [16].